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ABSTRACT

In the series of experiments supported by this grant, some fundamental characteristics of the concept of attention were explored. The first experiments were based upon the assumption that attention is limited and consequently that adult subjects may only be able to perceive a fairly restricted portion of the stimuli available to them at any moment in time. Our later studies, however, seem to indicate that this assumption is only partially correct. While it still seems true that attentional capacity is limited, the limitation probably occurs at the levels of language and thought. By contrast, perceptual capacity seems to be much less limited than had earlier been thought. The evidence for this statement comes in part from studies in which subjects were able to extract information from up to eight stimulus elements as quickly and accurately as from a single element. (Author)

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November, 1971

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In the series of experiments supported by this grant, some fundamental characteristics of the concept of attention were explored. The first experiments were based upon the assumption that attention is limited and consequently that adult subjects may only be able to perceive a fairly restricted portion of the stimuli available to them at any moment in time. However, our later studies seem to indicate that this assumption is only partially correct. While it still seems true that attentional capacity is limited, the limitation probably occurs at the levels of language and thought. By contrast, perceptual capacity seems to be much less limited than had earlier been thought. The evidence for this statement comes in part from studies in which subjects were able to extract information from up to eight stimulus elements as quickly and accurately as from a single element.

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Preface

The series of experiments carried out under this grant has been in large part a collaborative, team effort. The author would like to extend special thanks to the following for their help: William Bevan, David Blecker, Jeff Epstein, Howard Hock, Donna Grill, John Jonides, Arthur Kamlet, Norman Marcus, and Sally Wall.

INTRODUCTION

To the teacher in a classroom there are probably few psychological concepts as important as that of attention. Attention is important to the teacher because he feels that the ability of his students to learn is directly related to their attentiveness. When a pupil is distracted and inattentive learning is slow and difficult; when he is interested and attentive learning can be quick and painless.

It is interesting to note that such a casual and seemingly unscientific point of view has received strong support from rigorous laboratory investigations of discrimination learning. For example, Zeaman and House (1963) did a careful analysis of learning curves for relatively fast, moderate, and slow learning retarded children. These curves showed two distinct portions; A long flat attentional phase and a short rapidly climbing associative phase. The fast, moderate, and slow learning groups differed chiefly in the lengths of their attentional phases; apparently associations were formed about equally rapidly in all three groups. Other studies of discrimination learning have corroborated this observation that differences in overall learning speed among subjects depend upon attentional processes much more than upon associative processes.

Unfortunately, despite the obvious importance of attention, there is much that is not yet understood about it. The purpose of the proposed program of research was to explore some fundamental aspects of attention, in the hope that such basic research may eventually lead to an improved technology of education.

More specifically, the following questions were at issue in this research:

(1) What factors determine the degree to which a human can respond selectively on the basis of specified stimulus attributes, without his performance being impaired by irrelevant stimulus attributes?

(2) What is the most appropriate way to conceive of the mechanisms underlying selective attention--is it possible to locate "where" in the hypothetical chain of events involved in information processing selectivity is accomplished?

The conception of attention underlying these questions is based upon the (seemingly) limited information processing capacity of all organisms. A nervous system may be likened to a funnel in that its capacity for input or reception greatly exceeds its capacity for processing or output. Although the basis for the concept of attention was rooted in physiological necessity, the external manifestations of attention (e.g., a student's resistance to distraction) were considered to be learned, and thus capable of being modified.

The first experiments attempted under the foregoing schema were designed to study how a dimension of variation might become "attention-grabbing" by dint of extensive practice in responding to that dimension. These early studies failed. It proved to be very difficult to render any stimulus

dimension other than color interfering. Color, however, could be interfering from the very start of an experiment given an appropriate task. The overwhelming negativity of the first experiments led us to abandon the learning model for selective attention. It seemed more fruitful to investigate sources of interference that were so strong that they did not need enhancement during the experimental session. The color-word interference phenomenon discovered by Stroop (1935) recommended itself to us as a logical starting point. (These experiments are described more fully in the following sections).

The results of the Stroop-type experiments were very interesting and valuable. In general terms they suggested that interference is not simply a function of stimulus properties, but depends upon the nature of the task that the subject is performing.

At the same time that these studies of interference were being conducted, another set of experiments was being conducted in our laboratory. These studies were fundamental investigations into the nature of the concept of attention. Is attention, in fact, limited in amount? Can attention, properly directed, actually improve perceptual performance? These studies were as successful as the Stroop experiments and have led to a new conception of attention; they are described in the following sections.

METHODS AND RESULTS

Experiment I: Verbal Interference in a Perceptual Comparison Task

This study was done in conjunction with Arthur S. Kamlet and David L. Blecker and appears in Perception and Psychophysics, 1969, 6, 355-356.

The basic question is simple: Can a simple change in task render a dimension that is normally "attention-grabbing" ineffective as a source of interference?

Method: Experiment 1

Subjects. Ten male BA-level laboratory workers in the Human Engineering Laboratories at Aberdeen Proving Ground volunteered to serve in this experiment.

Stimuli. All stimuli were printed on colored plastic strips (1/2 x 1 1/4 in.) with a Dymo embossing tool. These strips were arranged on white cardboard sheets in five columns of 10 strips each. It should be noted that the embossing process results in white letters appearing on a colored background. The colors (and color words) used were red, yellow, green, and blue.

Conditions. There were six conditions, and for each a 50-item sheet was prepared. In Condition IE, color words were associated randomly with colored backgrounds. (Note: This resulted in about 75% incongruous associations, whereas most Stroop research has used 100% incongruity). In Condition IC, each colored strip had embossed on it four Xs. Thus, in this condition, there was no irrelevant verbal information and it served as a control for the preceding condition. In both of these conditions, Ss were asked to name the colors of the plastic strips as quickly and accurately as possible. In Condition IIE, the 50 strips were arranged in 25 pairs, one member of a pair directly above the other, and Ss were asked to state for each pair whether the colors of the strips were the same or different. The colors and words for this condition were selected to ensure that : (1) for about half of the pairs the correct response was "same," and (2) for about half of all pairs the verbal information was inconsistent with the color information, while for the other half it was consistent. As an example of inconsistent information, consider a pair in which both members are blue, but the top member reads blue while the bottom member reads green. The correct answer is "same" because the colors are the same, however, the two words are different and to the extent that a S comprehends their meaning he may be led to respond "different." Condition IIC was designed to serve as a control for the preceding condition; the colored strips were arranged similarly but they contained Xs rather than color words.

In Condition IIIE, color patches were again arranged in pairs and Ss were required to judge whether the colors were same or different, but instead of color words, the word SAME and the abbreviation DIFF were used.

As in Conditions IIE and IIC, the pairs were designed so that for about half of them the correct response was "same" and for the other half "different." The verbal material was introduced in such a way that it was inconsistent with the color information on about half of the trials and consistent on the other half. As an example of inconsistent information, consider a pair in which both members are red but both say DIFF. The correct answer is "same" because the colors are the same, but the verbal material may obtrude itself on the S and prompt him to respond "different." Unlike the situation in Conditions IIE and IIC, it seemed appropriate here to use the identical word for both members of a given pair. Condition IIIC, which was actually the same as Condition IIC, served as the control for Condition IIIE.

Procedure. The Ss were given the tasks in the order IC, IE, IIC, IIE, IIIC, IIIE, with a 1.5-min. break between trials. Following a 2.5-min. rest, they were then run through the tasks again in a similar fashion and in the same order. Their instructions stressed both speed and accuracy, and they were told to correct any errors as they went along. Timing was done with a stopwatch.

Method: Experiment 2

Essentially the same experiment was performed with 12 Johns Hopkins undergraduates serving as Ss. There were, however, several procedural differences. For one, the lettering was done with a silk-screen process and thus the words themselves, rather than their backgrounds, were colored. The words were considerably larger and there were only 48 items (or 24 pairs) to a sheet. The order of presentation of conditions was random with the restriction that a task (E) and its control (C) were always adjacent. The Ss were again run through all of the conditions twice, in two randomized blocks. Finally, the Es differed in the two experiments.

Results and Discussion

No particularly interesting practice effects were evident, and so the data from the two blocks were combined. In Table 1, the mean response time for each of the six conditions is shown separately for the two experiments. In examining these data it should be remembered that the comparative tasks (II and III) require only half the number of overt responses of the ordinary color-identification task (I) since the items are arranged in pairs. In addition to the mean times, the data for each experimental condition are expressed in terms of percentage decrement with respect to its corresponding control condition.

In addition to the obvious reconfirmation of the Stroop effect (IE vs IC), there are two important pieces of information in these data. First, incongruous color names seem to cause no interference at all with performance in the color-comparison task used in this experiment (IIE vs IIC). On these grounds, the task seems to provide an excellent testing ground for the hypothesis mentioned in the introduction. Second, there is a substantial

degree of interference in the comparison task when the verbal information is provided by the words SAME and DIFF (IIIE vs IIIC). These statements are verified both by the closeness of replication between Experiments 1 and 2, and by tests for matched samples (where significance is implied, $p < .01$; where nonsignificance is implied, $p > .10$).

Since the words SAME and DIFF do cause interference it is clear that the Ss were not insensitive to verbal meaning per se in the perceptual comparison task used in this experiment. However, these data leave another important issue unresolved. This is the question of whether the perception of particular words is dependent upon their closeness in meaning to the words that are used as responses in the task. It may be the case that all of the words used in the present study were equally well perceived and that degree of interference is a function of processes subsequent to word recognition. However, it is also conceivable that word recognition is itself dependent on the semantic similarity of the spoken and printed words. Further research is necessary to evaluate these alternative descriptions.

Further Comment

The complete lack of interference observed in Condition IIE deserves further discussion. One might think it due simply to the color words being effectively unrelated to the response words "same" and "different." However, as Klein (1964) has shown, in the usual Stroop color-naming task the presence of familiar words is distracting, even when these words are not directly related to the response words. This discrepancy between the present data and Klein's suggests that the nature of the S's task is, in fact, a determinant of the degree to which irrelevent information is interfering.

The counting task used by Derks and Calder provides another example of a task that seems to be relatively impervious to interference. The present authors have tried the color-counting task with sheets of material like those used in Experiment 1, but with the verbal material consisting of numerals. The data failed to indicate any interference due to the presence of the potentially interfering numerals. Why did the numerals fail to produce interference while SAME and DIFF did produce interference in Condition IIIE of the main experiment? The reason is probably that the counting task, unlike labeling or rendering a comparative judgment, can be accomplished so quickly that the meaning of the verbal material simply does not have time to produce interference.

Table 1: Response Times and Percentage Decrements

		Response Time (sec)		Percentage Decrement	
		Exp. I	Exp. II	Exp. I	Exp. II
IC	Stroop (Control)	23.9	25.4		
IE	Stroop	37.5	37.9	57*	49*
IIC	Comparison (Control)	14.5	15.2		
IIE	Comparison (Color Words)	13.8	15.3	-5ns	1ns
IIIC	Comparison (Control)	13.8	14.7		
IIIE	Comparison (SAME DIFF)	17.7	17.8	28*	21*

*$p < .01$
ns $p < .10$

Experiment II: Verbal Interference with Encoding in a Perceptual Classification Task

This study was done in conjunction with Howard Hock and appears in the Journal of Experimental Psychology, 1970, 83, 299-303.

In the previous study we showed that verbal interference from color names could be completely eliminated in a properly designed task. However, this leaves open the question of where interference occurs when it does manifest itself.

In the present experiment, there is once again no direct semantic relation between the printed words and the response words ("yes" and "no"). The task, however, is relatively "high level," requiring a decision as to whether an ink color belongs to a specified target set of colors. In addition, the size of the positive target set is varied so that the results can be interpreted with respect to the two-stage model of character recognition proposed by Sternberg (1967, 1968). This model requires the detailed analysis of the function relating categorization time to the size of the positive ("yes") target set. Sternberg has argued that the intercept of this function depends on the time necessary to form the stimulus representation, while the slope depends on the rate of comparison of the encoded representation with the representations of the target names in memory. Therefore, if the introduction of incongruous color names affects the intercept of the function and if there is no interaction between the type of printed material and the set size, the interference is with the identification or encoding of the ink color. If the presence of incongruous color names affects the slope, yielding a significant interaction, interference is with the memory comparison process. The model thus distinguishes the encoding of the ink color from the organization of the classification response.

Method

Stimuli. The stimuli for this experiment were decks of 20 3 x 5 inch index cards. Each deck consisted of one of three types of verbal material: a string of six Xs, a common verb (RUN, SKIP, DANCE, THROW, LISTEN), or a color name (RED, GREEN, BLUE, ORANGE, BROWN). The stimuli were hand-printed in red, green, blue, orange, or brown ink.

Subjects. Thirty-six undergraduates were paid $1.50 for participating in a session lasting 20 minutes. Twelve Ss were assigned at random to work with each type of verbal material.

Design. Each S worked with a single deck and thus with only one kind of verbal material. A target set of one, two, or three color names was defined by E for each trial. There were two trials for each set size, so that practice effects were counterbalanced for the different set sizes. The sequence of target set sizes was either 3, 2, 1, 1, 2, 3, or 1, 2, 3, 3, 2, 1. Sternberg (1963) found no differences in the reaction time vs. set size function when each S worked on several set sizes, as compared with

working on only one set size. Sternberg's (1967) procedure for balancing the stimulus and response uncertainty within each deck for the different set sizes was followed.

Both preceding and following the experimental trials, Ss were required to read the words "yes" or "no" on each of 20 index cards in another deck, following the same procedure as in the experimental trials. The time required to read through this deck was used as a covariate in order to reduce the variability between Ss in the motor aspect of the task.

Procedure. The deck of cards was placed face down in front of S. The S was required to turn the cards over one at a time, indicate with a "yes" or "no" response whether or not the ink color belonged to the target set, and place the card face down into a $4\frac{1}{2}$ x 6 inch box. The time necessary to proceed through the deck was recorded to the nearest .5 sec. with a stopwatch. The deck of cards was shuffled between trials.

The Ss were instructed to proceed through the deck as quickly as possible without making any errors. If they did make an error, they were instructed to try to correct it. The Ss were cautioned to moderate the speed of their motor movements so that the index cards were always placed in the box.

Results

The two measures on the covariate task for each S were combined, and a covariance adjustment was made on the sums of squares for the type of verbal material, the sequence of experimental conditions, and their interaction. Winer's (1962) procedure was followed, using S variability within combinations of these two variables for the adjustment. The regression coefficients within each type of verbal material were found to be insignificantly different from the overall regression coefficient, $F\ (2, 24) = 2.79$, $p > .05$, indicating that the coefficients are homogeneous with respect to this variable (Edwards, 1968). The same was found to be true for the sequence variable, $F\ (1, 24) = 1.54$, $p > .10$.

The function relating adjusted mean categorization time to the size of the positive target set is indicated in Fig. 1. It can be seen that the type of verbal material affects the intercept of the function; this effect is statistically significant, $F\ (2, 29) = 13.96$, $p < .005$, supporting the main hypothesis of the experiment. The size of the positive target set, as suggested by the positive slope of the function, is also significant, $F\ (2, 60) = 85.56$, $p < .005$. The Type of Verbal Material x Size of the Target Set interaction was not significant, $F\ (4, 60) = 1.58$, $p > .10$, as may be seen in the virtually parallel curves found in Fig. 1.

The practice effect due to working on each target set size twice was significant, $F\ (1, 30) = 36.66$, $p < .005$. This reflects both improvement in the required motor movement and speed of information processing. More specific practice effects are indicated by interactions. The Practice x Set Size interaction was significant, $F\ (2, 60) = 12.90$, $p < .005$, resulting in a decreased slope and indicating that practice improves the rate of processing

target items in memory. Although the Practice x Type of Verbal Material interaction was not significant, $F(2, 30) = 1.15$, $p > .10$, it can be seen from the second block of trials in Fig. 1 that practice tends to make the common verbs more interfering. Finally, the absence of a significant Practice x Target Set Size x Type of Verbal Material triple interaction, $F(4, 60) = 2.44$, $p > .05$, indicates that practice did not affect the parallel relationship of the curves in Fig. 1.

Since the size of the target set did not interact with the type of verbal material, the linearity of the sorting time vs. set size function can be evaluated for all types of verbal material from the linear trend of the set size variable. The linear component is highly significant, $F(1, 60) = 170.04$, $p < .005$, while the quadratic component is not significant, $F(1, 60) = 1.07$, $p > .10$.

Discussion

The presence of a significant effect for the type of verbal material indicates that interference can be obtained when there is no direct semantic relation between the printed verbal material and the required overt response. This confirms the view of Egeth et al. (1969) that color-word interference should appear in tasks which involve the cognitive apparatus rather than in "low-level" perceptual tasks. While Klein (1964) found an interference effect in the absence of a direct semantic relationship, the response competition hypothesis would predict no difference between the "verb" and "color-word" conditions of this experiment; both sets of words are familiar and bear no direct semantic relation with the response words. It can be seen from Fig. 1 that the two sets of words are not equally interfering.

Since the obtained interference effect does not seem to be attributable to overt response competition, it is of interest to examine how the stimulus information is processed by S. Following Sternberg's (1967, 1968) model, the absence of a significant Type of Verbal Material x Size of Target Set interaction indicates that the verbal material distracted from the identification or encoding of the ink color and did not affect the classification process. This conclusion converges with Gholson and Hohle's (1968) finding that in a color identification task, the introduction of incongruous color words did not interact with set size. Sternberg (1968) found in a choice reaction time experiment that the number of choices strongly interacts with the difficulty of response organization (the correct response was either the name of the perceived numeral or the name of the numeral plus one). Therefore, Gholson and Hohle's failure to obtain an interaction suggests that the interference effect is not on the response selection process.

It seems that cognitive tasks requiring high-level encoding proceed slowly enough for the printed material to distract from the encoding of the ink color. Low-level perceptual tasks, like those of Egeth et al. (1969), Derks and Calder (1969), and Pritchatt (1968), involve encoding which is rapid enough to eliminate distraction by the printed material. Thus, the extent to which a task affects encoding time determines the amount of interference or distraction. This conclusion is incompatible with Klein's (1964) view of response

competition as a spur to seek restimulation, resulting in increased encoding time. It seems more likely that interference or competition for attention is the result, rather than the cause, of increased encoding time. Klein has claimed that the degree of semantic relation between the printed material and the required overt response determines the amount of restimulation needed for a correct response. In the light of the conclusions drawn in the present study, it is more plausible that S is sensitized to words which are semantically close to the required response words. Such words would be recognized sooner and further distract from the encoding of the ink color. This conceptualization is now under investigation.

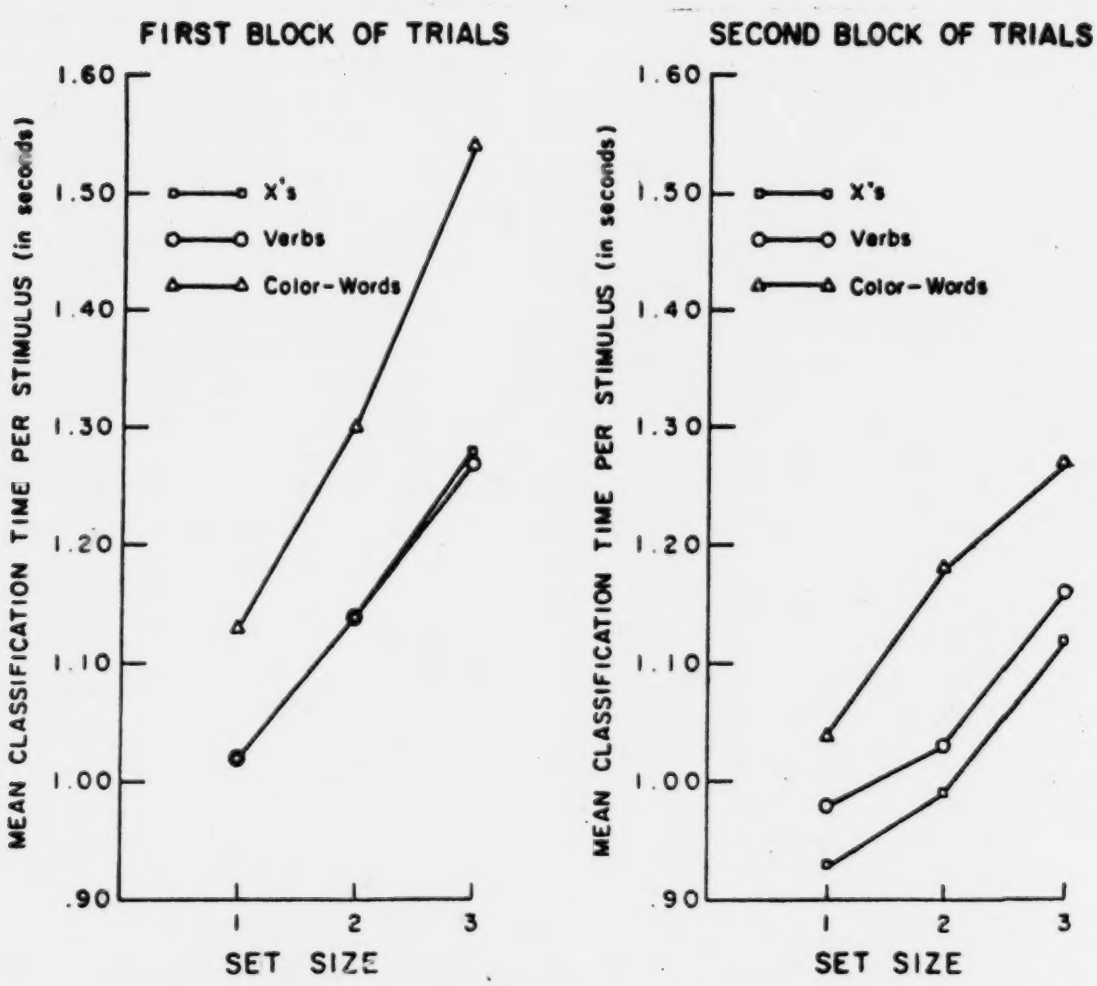

FIG. 1. Adjusted classification time per stimulus card as a function of the size of the positive ("yes") target set for each kind of verbal material within each block of trials.

Experiment III: The Nature of the Effect of Set on Tachistoscopic Recognition

This study was the doctoral dissertation of Robert G. Pachella. It is now being prepared for publication.

The preceding studies were concerned with the role of attention in situations where irrelevant information might be interfering. The present study is concerned with an issue which is nearly the logical opposite: Can attention improve performance by focusing on highly relevant information in a complex picture? In other words: Is set a perceptual phenomenon and can it improve performance in a perceptual task?

To investigate these questions, subjects were required to decide whether or not a briefly presented picture of a common object was the same as a specified alternative. The alternative was presented either before the stimulus exposure or after it. In experiment I, the alternative was either the picture of an object or the name of an object. Results indicated that subjects presented with a picture alternative before the stimulus were more sensitive (using the bias-free sensitivity measure, A_g) than subjects receiving the picture alternative after the stimulus. On the other hand, when the alternative was the name of an object, presenting the alternative before the stimulus resulted in a significant change in response criteria but no change in sensitivity. In experiment II the subjects were shown all of the stimulus pictures, for 10 sec. each, 24 hours prior to the experimental session. During the experimental session, the subjects were presented with name alternatives either before or after the stimulus flash. Results indicated that subjects receiving the alternative after the stimulus were no more sensitive than the corresponding subjects in the name-after condition of experiment I. However, with the alternative presented before the stimulus, the subjects performed as well as the subjects of the picture-before condition of experiment I.

Several points should be made about these results. It can be concluded safely that the effect of setting a subject with the name of an object produces no change in the sensitivity of the subject, but merely results in a criterion shift. This is a simple description of the empirical result. The nature and significance of the particular shift taking place should be noted; however, it is not a general shift of response criteria that takes place, but a highly specific one. The subjects in the present experiment who were set with the name of an object, are not simply more likely to say same than different, thus, yielding a larger percentage of correct scores on same trials (i.e., a higher hit rate). What they are capable of doing, is reporting that they actually "see" something. They do this in spite of the fact that what they "see" is no more likely to correspond to the actual stimulus than the reports of subjects in the after condition.

Stating this conclusion in a more general way, it is being argued specifically that subjects in both the before and the after name conditions extract the same kind and amount of information about the stimulus. It is this extracted information that determines whether or not the subject's judgment

will be correct with respect to the actual stimulus. However, subjects in the before condition (i.e., subjects who are set) organize the extracted information into a "percept." This is the nature of the interpretation process for these subjects. The subjects in the after condition (i.e., subjects who are not set) do not form a percept. The interpretation process for these subjects consists of an essentially cognitive (as opposed to perceptual) judgment which evaluates the extracted information with respect to the alternative presented after the stimulus. These subjects, thus, never have any particular perceptual experience of the stimulus.

Experiment IV: Attention

This paper was written in conjunction with William Bevan and is in press as a chapter in the Handbook of Psychology.

This paper does not report any original research as it is a theoretical analysis of the concept of attention. In this analysis two aspects of attention were distinguished, the selective and intensive. Selective attention refers, in part, to the kind of phenomena studied in Experiments I - III, while the intensive aspects of attention refer to such phenomena as attentional capacity, span of attention, and vigilance. Several of the following studies are concerned with the concept of attentional capacity, and in one particular experiment, attentional capacity is investigated within the context of the span of attention paradigm.

The Attention chapter itself is much too long and involved to be described in brief compass here.

Experiment V: Variables Influencing the Mode of Processing of Complex Stimuli

This research was the doctoral dissertation of Donna P. Grill, and appears in Perception and Psychophysics, 1971, 10, 51-57.

Previous work in this laboratory has been based on the implicit assumption that attention is limited in amount. If it is so limited, then one consequence may be that all of the dimensions of a complex stimulus are not processed simultaneously. However, it is conceivable that after practice the dimensions of complex stimuli may be processed simultaneously. Grill's thesis was directed, in part, at these points.

Within the past few years, attention has been directed toward the mode of processing of information provided by complex stimuli. One of the questions of chief concern has been whether information about several dimensions is processed simultaneously (in parallel) or one dimension at a time (serially). In other words, an implicit assumption on which this research has been based

is that human organisms are either serial processors or parallel processors. However, the present study is founded on the assumption that humans may be capable of performing in either of these modes (and, perhaps, others as well) and that the most profitable line of study is one which attempts to specify the conditions under which parallel and serial processing can occur.

On the basis of the results of previous research, it seems fairly obvious that expecting to resolve the categorical issue of serial vs parallel processing is at least unrealistic if not unwarranted. Instead, it would appear that the most profitable direction for research would be to ascertain the factors that are potential sources of variation among the results of previous studies and then to vary these factors systematically in order to determine how they affect the mode of processing. After the critical variables have been studied, we should be able to specify the combinations of these variables which will result in the various modes of processing.

The present study attempts to specify some of the conditions under which parallel and serial processing may occur. The three variables studied were (1) type of task, (2) relative set for speed vs accuracy, and (3) practice. Pairs of multidimensional, geometric stimuli were presented either simultaneously or successively to S who was required to indicate whether they were the same or different. Each S participated in nine sessions. For half of the Ss speed was emphasized, and for the other half accuracy was emphasized. The results indicated that : (1) responses were faster with successive presentation than with simultaneous presentation; (2) with successive presentation, processing was serial; (3) in the simultaneous presentation condition, a gradual shift from serial to parallel processing occurred with practice; and (4) the speed and accuracy instructions used in this experiment produced no differential effects on latency or errors.

Experiment VI: Parallel Processing of Multielement Displays.

This research was done with John Jonides and Sally Wall and is in press in Cognitive Psychology.

Grill's thesis showed that processing could change, with practice from parallel to serial. Are these circumstances in which processing might be parallel from the very start of practice? This question was investigated in the context of the classical span of attention experiment.

In recent years considerable effort has been devoted to the analysis of tasks in which Ss must respond on the basis of information contained in a briefly presented display such as an array of alphanumeric characters. There have been two main thrusts to this research. One has been to develop measures of the "span of apprehension" in the absence of response or memory limitations (e.g., Sperling, 1960), while the other has been to determine the mode of processing of such displays (e.g., Estes & Taylor, 1966). This latter topic forms the focus of the present study. More specifically,

this research is designed to explore the parallel/serial processing issue that has received so much attention in recent years (see, e.g., Corcoran, 1971, Chapter 2).

Perhaps the best method for studying perceptual aspects of visual information processing is the detection paradigm, which is a generic name for a variety of experimental tasks. What these tasks have in common is that the S is asked to make a simple response such as a key press as soon as he detects some predefined aspect of the display. In contrast to the previously described paradigms, the response is very simple and there is little need for S to load the display into short-term memory because he knows what to look for and can start processing immediately upon presentation of the stimulus array. Of course memory is implicated to the extent that the criterion for response is difficult to remember.

The two major varieties of detection tasks are search and same-different discrimination. In a search task an S may be asked to indicate whether or not a particular element, called the target, is present in the array; this may be referred to as a yes-no (or presence-absence) response. Alternatively, S may be asked to indicate which one of two (or more) specified target elements is contained in an array; this is a forced-choice response. In the same-different task, Ss are asked to indicate whether the elements of the array are all identical to one another or whether (at least) one element differs from the others.

In the present research, search (presence-absence) and same-different tasks were used. The number of elements in the displays varied randomly from 1-6 in the search experiments and from 2-6 in the same-different experiments.

The result of major interest is that in several experimental conditions reaction was unrelated to the number of elements in the visual display. For example, to determine whether all of the elements of a display were the same or whether the display contained a single discrepant element took the same amount of time regardless of whether 2, 4, 6, or 8 elements were shown. This was true as long as the discrepant element was distinctly different from the others. The same conclusions also resulted from a search task when the target was distinctly different from the nontarget elements. The most interesting result was that RT was unrelated to N, even when the target was defined as "any digit" and the nontargets were a random array of letters. These results suggest that the elements of a complex display are processed in parallel, which is contrary to most previous research on the topic.

Experiment VII: Differential Effects of Familiarity on Judgments of Sameness and Difference

This research was done with David Blecker and appears in Perception and Psychophysics, 1971, 9, 321-326.

In much of our previous research, we have required very simple responses from our Ss; commonly they are asked to indicate whether pairs of stimuli are the same or different. This response has been used because it is uncomplicated and relatively free of bias. For these reasons, it struck us that it might be useful to measure the latency of same-different responses when the elements of the pairs were either familiar or unfamiliar. We could thus study the effects of familiarity on perception with response bias controlled and perhaps clear up a long-standing methodological impasse.

Method and Results

The spatiotemporal characteristics of mechanisms that extract information from complex alphanumeric displays were investigated in a series of experiments using search and same-different detection tasks. Under several (but not all) experimental conditions, the functions relating reaction time to the number of elements in the display were flat. Such data are consistent with an unlimited-capacity parallel processing model. Interestingly, this model was appropriate even in a search task in which the target was specified as any digit and the nontargets were a random assortment of letters.

Discussion

Familiarity. The present results stand in direct contrast to the results of previous experiments that used a perceptual comparison task, since those studies reported no effect of familiarity on perception. However, this discrepancy cannot be considered surprising in view of the procedural details of those experiments as presented in the Introduction. The present conclusion also stands in contrast to other recent investigations which have led to the conclusion that familiarity may influence memory or response bias but not perception (e.g., Smith, 1967; Broadbent, 1967).

Is the present research an anomaly, perhaps the result of faulty equipment or even E bias? This now seems unlikely. Two as-yet-unpublished reports confirm the finding that familiar items can be compared more quickly than unfamiliar items (Eichelman, 1968; A. Yonas, personal communication). In addition, there are two other recent studies, using quite a different task, that provide very strong evidence of familiarity affecting perception (Reicher, 1969; Wheeler, 1970). Reicher tested the recognition accuracy of the individual letters of a word with a forced-choice procedure. The stimuli were presented tachistoscopically, and the position of the letter to be guessed was made known to the S by means of a poststimulus cue. The results showed that recognition of a letter was more accurate when it was part of a word than when it was part of a meaningless quadrigram.

Wheeler's study eliminated some possible artifactual causes of Reicher's results and led to the same conclusions. These were excellent, well-controlled studies; it does not look like familiarity effects can be dismissed as "non-perceptual" any longer.

Two directions for further research now seem evident. First, a more detailed analysis of the construct of familiarity is needed. Clearly, letter rotation and rated meaningfulness are very different kinds of manipulations, and it would be surprising if their perceptual effects were identical. Perhaps there are several kinds of familiarities, each having a distinghishable effect on perception. Second, more analytic methods should be used to find the locus (or loci) of the effects of familiarity. To simply say that there are perceptual effects is to stop short of the most interesting aspects of the investigation. Perhaps a stage analysis, as described by Sternberg (1969), would be a fruitful approach to the localization problem.

Judgments of Sameness and Difference. Surely the most surprising aspect of the present research was the repeated finding that the familiarity effect obtained for "same" judgments but not for "different" judgments. Reaction-time data for "same" and "different" judgments have frequently puzzled psychologists. What has been perplexing is that "same" judgments have sometimes (although not always) been shown to be significantly faster than "different" judgments. This finding is especially troublesome for investigators who think in terms of perceptual models based on feature analysis. On such a model a correct "same" judgment must be the result of an exhaustive comparison of all of the relevant features of the pair of stimuli. However, a "different" judgment might be based on a self-terminating comparison process, stopping as soon as a difference is detected in any feature. But even if the matching process were not self-terminating, an unembellished feature testing model would not lead to a prediction of longer times for "different" judgments than for "same" judgments. A radical solution to the problem is simply to stop trying to make a single kind of process account for both "same" and "different" judgments.

The data from the present series of experiments clearly support the hypothesis that "same" and "different" judgments may be initiated by independent processes. This is evidenced by the repeated finding that "same" responses are affected by familiarity but "different" responses are not. Unfortunately, it is difficult to go beyond this general statement, because the data from Experiments 4 and 5 (trigrams) differ in an interesting and important way from the data of Experiments 1 and 2 (letter pairs) and from Bamber's data. The difference is that where Bamber found "sames" to be consistently faster than "differents," we find this to be true for pairs of single letters, but not for pairs of trigrams. The reason for this discrepancy is not yet clear. Thus, although we have concluded that "same" and "different" judgments are not opposite sides of the same coin, our reasons are quite different from Bamber's.

The present results invite (but do not demand) the speculation that the difference detector is relentlessly featuristic, whereas the sameness detector is responsive to the configuration of the presented form. It seems that only by being responsive to the properties of the overall configuration

can the sameness detector use one of those properties (i.e., familiarity) to guide the feature analysis that is going on at the same time within the complex process of sameness detection. Such a seemingly backward mode of operation, from the whole to part, seems to be demanded also by the Reicher (1968) and Wheeler (1970) studies.

Experiment VIII: Laterality Effects in Perceptual Matching

As the same-different task has proved to be very fruitful in several of our previous studies, we applied it next to the analysis of laterality effects in perception. This study appeared in Perception and Psychophysics, 1971, 9, 375-376. Laterality is important to a theory of attention, and also is importantly related to the study of reading.

Method

Two experiments were performed in which Ss had to indicate whether pairs of simple geometric forms were "same" or "different." In Experiment 1, the two forms were either both in the left visual hemifield or both in the right hemifield. Reaction times were unaffected by the locus of the stimuli. In Experiment 2, in addition to left and right pairs, there were pairs in which one of the stimuli was on the left and the other was on the right. Under these conditions, reaction times were faster for pairs totally on the left than for pairs totally on the right. The data support the notion that implicit scanning patterns are important in determining laterality differences. When such scanning is not involved and when simple nonverbal stimuli and responses are employed, laterality differences are eliminated.

General Discussion

The first experiment failed to yield any laterality difference between the left and right visual fields. Moreover, there was no indication that responding to sameness or difference or with the right or left hand made any difference at all in the speed of response. Experiment 1 invites the conclusion that in the absence of any substantial memory load or apparent scanning strategy, laterality differences evaporate.

By contrast, the second experiment, containing bilateral presentations, yields a clear superiority of the left visual field over the right visual field. This would seem to be consistent with the results of previous research which shows left-field superiority with bilateral presentations. However, these data must be interpreted with great care. The crucial point is that the left and right trials in Experiment 2 are actually unilateral presentations because both elements of the pairs are on the left or both are on the right. The left-right comparison in this experiment is based on exactly the same kind of trials as the left-right comparison of the first experiment. Thus, the existence of bilateral trials induced a laterality

difference in what are basically unilateral trials occurring within the same random sequence. However, this seemingly paradoxical result still seems to be consistent with the postexposural scanning hypothesis if we assume that on a bilateral trial the S attempts to match by scanning (implicitly, not with an eye movement) from the left element to the right element, the scanning direction consistent with long-standing reading habits. Since half of the trials were bilateral, it may be assumed further that the preference for starting the implicit scan at the left is carried over to the unilateral presentations in the same sequence of trials.

Even if the plausibility of this argument is granted, a problem remains. Why did a laterality difference obtain in most previous work using unliateral presentation but not in the present Experiment 1? The answer is not yet clear, but we may tentatively suggest that a right-field superiority results when verbal material or material to be remembered is presented to the right visual field and, hence, to the left cerebral hemisphere which is the locus of the language center (e.g., Gazzaniga, 1967). In Experiment 1 the stimulus material as well as the response were nonverbal, the task was one of the simple perceptual comparison, and implicit scanning did not seem to be implicated. In these simplified circumstances no laterality effect occurred. Further research with matching tasks and a variety of stimulus materials may permit the determination of the extent to which the verbal nature of the stimuli may be a determinant of laterality differences.

Experiment IX: Spontaneous Encoding of Left-Right Orientation

Some of the most theoretically interesting and practically important problems in the field of cognitive development center on the ability to respond on the basis of stimulus orientation. This topic is especially important since reading deficiencies have frequently been attributed to an inability to differentiate stimuli that differ only in orientation (e.g., M vs. W, b vs. d). In the present experiment we were interested in studying the development of the tendency to spontaneously encode and remember the orientation of stimuli.

The basic paradigm is very simple: children were shown a series of pictures, the pairs of items were presented in which one member of the pair was identical to one of the pictures previously shown while the other pair member was the mirror-image reversal. Subjects were asked to select the one that was seen before. It should be made clear that this was essentially a study of encoding and memory, and we did not foresee any difficulty with subjects not "seeing" the difference between mirror-image reversals of the same picture (e.g., Robinson and Higgins, 1967).

To our knowledge there are no previous studies on the topic of "memory for picture orientation," although there are interesting leads within the large literature on discrimination learning. There seems to be general (although not complete) agreement that children have difficulty in discriminating among stimuli differing only in the orientation in which they are presented. The greatest difficulty seems to be in differentiating stimuli which are left-right mirror-images. Rudel and Teuber (1963) found that children up to the age of six could not learn a right-left mirror-image discrimination but mastered an up-down mirror-image problem reliably from the age of 3 1/2. Huttenlocher (1967) found that when asked to place stimuli next to a standard in "exactly the same way," errors consisted mainly of the mirror-images of the standard stimulus. Errors were maximal when the test stimuli were to be placed beside the standard--left-right mirror-images resulted.

Huttenlocher explained her results by stating that children are insensitive to mirror-image rotations of the stimuli, the greater difficulty with left-right discriminations being due to the preponderance of bi-laterally symmetrical objects in the natural world. Right-left discriminations need not be made routinely to respond to everyday stimuli appropriately, while up-down discriminations are more critical i.e., the milk falls out of the glass if it is inverted.

Ghent (1961) developed the hypothesis that children have a tendency to scan a stimulus from the top down, from results which indicated that upright orientation of the standard stimulus was critical when the comparison stimuli were presented tachistoscopically in varying orientations. Little information relevant to a left-right reversal discrimination would be encoded from such a scan.

Experimentally, discrimination among differing orientations can be strongly affected by the procedure, particularly by how much information can be gleaned from the testing situation as to what variables are experimentally important (Caldwell and Hall, 1970), and by the stimuli used; different stimuli being differentially affected by changes in orientation (Arnoult, 1954; Dearborn, 1899; Sato, 1960). Much of the difficulty encountered by Rudel and Teuber may be due to the use of extremely simple, abstract stimuli. Newhall, (1937) found that orientation is less critical for discrimination of familiar objects. Training in discrimination desired also significantly affected performance (Hendrickson and Huehl, 1962), indicating that orientation discrimination may be learned and that results may be contaminated by learning within the experimental situation.

The present procedure investigated whether children of different ages spontaneously encoded and remembered left-right orientation information from a visual stimulus which approximates naturally occurring visual situations.

Method

Ninety-seven children from two preschool groups and kindergarten, first, second, and third grades at the Lida Lee Tall Learning Resources Center participated in the experiment. Kindergarten and first grade children were divided into an experimental (Reversal) group and a control (Content) group according to standing on the Metropolitan Readiness Test. Second and third grade children were matched according to the MAT word recognition scores, in an attempt to have groups of equal ability. Preschool children were randomly assigned to experimental or control groups.

Subjects were tested individually in test sessions approximately 15 minutes in length. Children in both groups were shown 20 slides; pictures from children's books, photographs of people, and nature scenes, each slide presented for 10 seconds. Immediately following the presentation of this standard series, both groups were shown pairs of slides and requested to select from the two alternatives presented one above the other, the picture that had been shown to them before. Placement of the correct alternative was determined randomly with an equal number of correct choices at each location, 10 on top, 10 on the bottom.

The Content group pairs consisted of one slide from the standard series and one slide not previously shown. The content of the pairs was matched i.e., book pictures were paired with other book pictures, human faces with other human faces, and nature scenes with nature scenes.

The Reversal group subjects were shown pairs consisting of a standard series slide and its mirror-image reversal.

The younger children were tested in the presence of a teacher or childrens aide in an attempt to make the testing situation as comfortable as possible. Children were encouraged to point to the correct answers to eliminate possible confusion over verbal labeling of location.

The entire procedure was repeated with college students at Johns Hopkins University to provide information on adult performance.

The purpose of the control group was to determine whether S's memory for pictorial content (as opposed to orientation) was high enough to make the test of memory for orientation meaningful. Nearly perfect performance from Ss of all ages was expected in the control task.

Results and Discussion

The mean number of correct responses for all age groups on both tasks as well as the number of subjects contributing to that mean are given in Table 2 (see page 25). There does seem to be a developmental trend with gradual improvement with age until adult performance levels are attained by the 3rd grade - 8 years of age, on the reversal task. As was expected, all ages perform well in the content task.

Only two of five subjects in the 3-year preschool reversal group successfully attended to and completed the experimental task. However, it should be noted that both of these children had passed their fourth birthdays. No three-year-old tested was able to successfully complete 20 trials of the reversal task. It is not clear whether this was due to a failure to understand the directions, or attend to the task, or a failure to encode and remember orientation. However, of four three-year-olds tested, 3 successfully completed the equally long content task with a mean number correct of 18.4 indicating that three-year-olds are capable of responding in the experimental situation. The four-year-old group performed at the level of chance in the reversal task but attained a mean number correct of 17.4 in the content task. These data, based on very small Ns, tentatively suggest that three and four-year-olds do not spontaneously encode and remember orientation.

The range of scores on the reversal task were quite large, even at third grade and adult levels. Some individuals do not seem to be able to encode and remember orientation. Surprisingly, performance on the reversal task was not related to ability scores, handedness, or diagnosed learning disabilities. Students who exhibited mirror-writing were still capable of distinguishing mirror-images in the experimental task.

The better than chance performance of the five and six-year-old groups on the reversal task would seem to indicate that Rudel and Teuber's inability to train six-year-olds on a mirror image task may have been due to the type of stimuli used. Most certainly the children in the reversal group of the present experiment were encoding and remembering the orientation of the stimuli to some extent. The results indicate that much of the present literature claiming that children are insensitive to mirror-image rotation, especially left-right rotations, may be due to procedural rather than developmental variables.

These results are more provocative than conclusive. The task must be used on a much larger sample in order to make any definitive statements about normative performance, but if the present findings are valid, further research is needed to determine if three and four-year-olds can be taught to

encode and remember orientation information and implications for theories of learning and perceptual development should be investigated. Further investigation should be carried out in order to determine the basis of the wide individual differences and to what they may be related.

TABLE 2

Number and Mean Number Correct for Six Age Groups on a Mirror-Image Reversal Discrimination and a Content Discrimination Task with Range of Scores for the Reversal Group

	Reversal Group			Content Group	
Age Group	N	X # Correct	Range	N	X # Correct
3 Yrs.	2*	14	12-16	3	18.4
4	7	10.5	9-12	3	17.6
5	11	14.4	8-20	7	19
6	12	16.3	8-20	10	19.3
7	11	16.4	11-20	11	19.6
8	9	17.4	11-20	11	19.9
Adult	16	17.4	14-20	16	19.9

*Both of these children, although in the 3-year age group, had passed their 4th birthdays.

Experiment X: The Role of Structure in the Perception of Familiar and Unfamiliar Stimuli

The work was the doctoral dissertation of Howard Hock, and is now being prepared for publication.

There were several interesting findings in this work. However, in the context of this report we will emphasize just one of his results. Using random dot patterns that were completely unfamiliar to Ss at the outset of the experiment, Hock "built-in" various degrees of familiarity during training trials. He then completely replicated the results obtained by Egeth and Blecker (1971) described earlier. Thus, the dissociation of sameness and difference is not the artifactual result of using alphabetic stimuli.

Conclusions

This final report summarizes the findings of ten separate publications. The preceding section, entitled Methods and Results, contained a fairly complete summary of nine of those papers (the fourth being too long and complex to be summarized briefly in this report). Therefore, it would be redundant to reiterate as Conclusions what has already been said under the rubric of Results. However, it is possible to make a few general comments about the subject matter under investigation--attention.

Perhaps the most important conclusion we have reached is that there is little reason, if any, to think that attention is limited in capacity at the perceptual level. Experiment VI speaks directly to this point. Even where perceptual attention seems limited (perhaps in Experiment V where serial processing was found) practice may suffice to eliminate the apparent limitation in capacity.

The results of Experiments I and II are generally consistent with what we have concluded about perceptual capacity, although there was some interference between color and word at the level of stimulus encoding. It seems now that attention is most severely limited at the level of cognition and response execution (as opposed to perception). Some additional conclusions:

1. A beneficial effect of mental set was found in a perceptual comparison task.

2. Familiarity does influence perception. This was found in a series of perceptual comparison tasks.

3. Judging that two stimuli are the same involves psychological processes that are different from those involved in judging that two stimuli are different.

4. Attention is directed about equally to the two halves of the visual field, unless a stimulus sequence is contrived to bias the direction of attention.

5. Many children, and some adults, do not spontaneously encode and remember the orientation of the stimuli that they see. Moreover, some children who write backwards did show evidence of spontaneous encoding of orientation. These data suggest that some interpretations of dyslexia or agraphia may be oversimplified.

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